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Groundwater Quality Assessment in Iworoko-Ekiti Environs, South-Western Nigeria Using Chemical Indices: Implications for Irrigation and Household Utilities

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Abstract

Groundwater quality of Iworoko-Ekiti and environs for irrigation and domestic purposes has partly been established using chemical indices. Groundwater quality assessment in the area is of great importance because of the influence of various activities in the area. The area is thickly populated by citizens and higher institution students across Nigeria. At the moment, sanitary conditions are very poor as the main occupations are trading and farming. Nineteen hand-dug wells were randomly sampled within the settlement. Flame photometry and spectrometry were used for cations and anions analyses respectively. Average values of pH, EC and TDS are 7.02, 342µS/cm and 230ppm. The average trend of major cations and anions concentrations is $Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$ and $HCO_3^{-}>Cl^{-}>SO_4^{2-}>CO_3^{2-}$ respectively. Average values of Degree of Contamination and Revelle Index are 14 and 0.6 respectively. SAR, MAR, %Na, KI, TH, CIA-1 and CIA-2 has an average value of 0.7, 37.4, 24.8, 0.3, 162ppm, 0.4 and 0.9 respectively. Based on these values, the water is suitable for irrigation. In general, 31.6% of the hand-dug wells are slightly acidic and 10.5% have Revelle index >1 above recommended values respectively. 10.5% from the hand-dug wells have KI above one, 5.3% has MAR above recommendation making them unfit for irrigation purposes. Hence, majority of the wells are suitable for irrigation with exception of a few wells. However, the elevated Cl^{-} concentrations in all the wells, make them unfit for human consumption. Weathering of migmatite and granite gneisses together with anthropogenic activities really contributed to the chemistry of the groundwater.

1. Introduction

The geoscientific investigation of the quality of subsurface water resources is very crucial and essential for the socio-economic advancement of every community and society. The study of water quality for various purposes in human life has not been given serious attention most especially in rural areas within the nation Nigeria [1],

[2]. It is essential that the chemistry of water should be examined before utilizing it for domestic or irrigation purposes. Some water sources may be rendered unsuitable for consumption based on environmental influence [1], [2], [3]. From the review of the groundwater quality in Nigeria and based on the data in available previous work, it was discovered that the values of some measured physicochemical parameters were very high due to influence of weathering of rocks and other anthropogenic activities [4]. It has been reported also that in the developing world, about 80% of all diseases are linked to poor drinking water and unsanitary conditions. Water with high levels of dissolved solids may lead to high concentrations of salts in water and soil which can affect crop yields [1],[2],[5],[6]. The suitability status of an aquifer can be determined using chemical indices to unravel the level of elemental concentrations which might be injurious to the consumers and crop yields [1], [2], [7]. Hence, this research aimed at establishing the quality of groundwater in Iworoko and its environs using chemical indices.

2. Methodology

2.1 Description of the Study Area

The map of the study area with groundwater sampling points is presented in Figure 1. Iworoko is under Irepodun/Ifelodun local government area of Ekiti State, Nigeria. It was reported that the study area is underlain by Precambrian period of south western Nigerians' basement complex. This complex has been reported to be part of the three main litho-petrological components that made up the geology of Nigeria which in turn formed part of the Pan-African mobile belt. Lithologically, the study area comprises of granite, migmatite gneiss (with dominant mineral assemblages of quartz, mica, plagioclase and hornblende) and granite gneiss (with dominant mineral assemblages comprising of quartz, feldspar and mica) (Figure 2) [8].

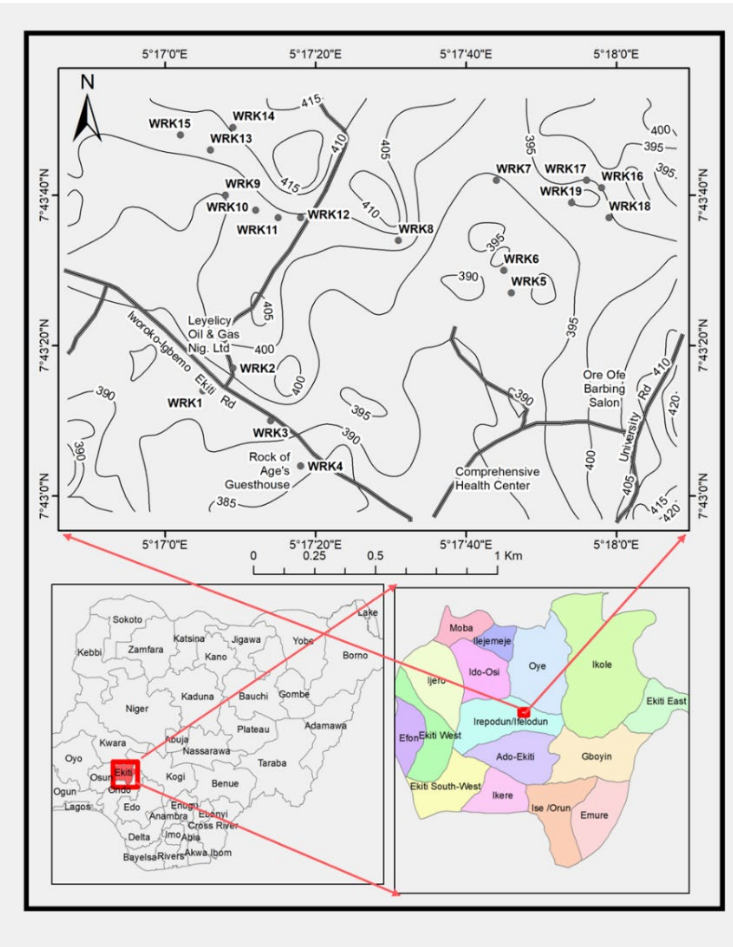

Fig. 1 *The position of Iworoko and environs in topographical map illustrating the sampling points [9]*

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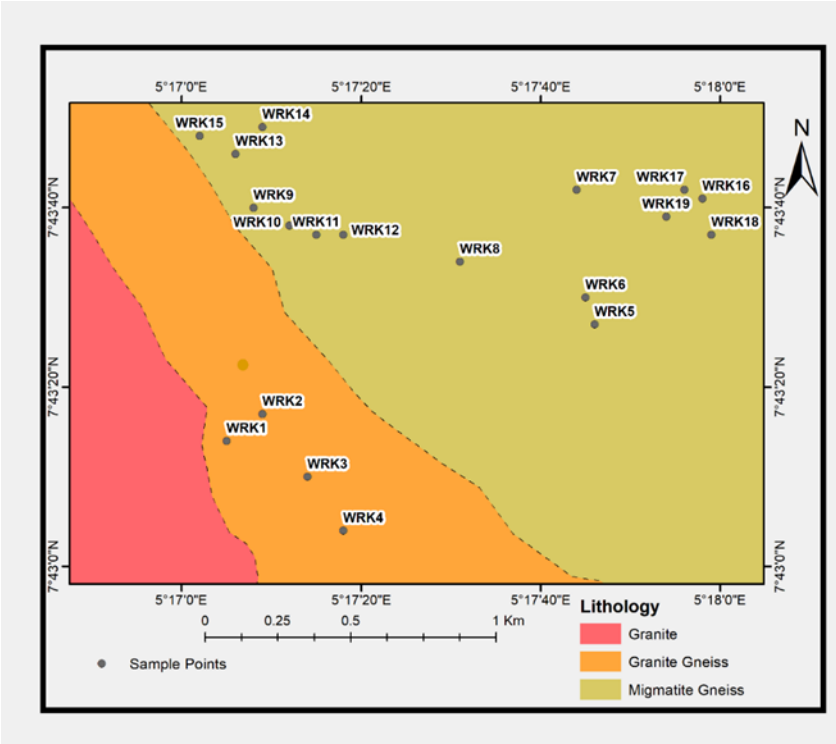

Fig. 2 *Geological map of the study area (carved from geological map of Nigeria) [10]*

The main occupations of the denizens are trading, farming and schooling. Several students of Ekiti State University, Nigeria are residing in the area. The area has a small landmass, thickly populated (with the students and the indigens) and with a poor sanitary system. The climate falls within the tropical region of west Africa countries.

2.2 Data Collection

Nineteen samples of hand dug well water were randomly collected from the water resources within the study area during the dry season. White water bottle containers were rinsed several times with the sample water before the actual water sampling. The GPS reading of every sampling point was recorded. The majority of the hand dug wells were drilled through the Migmatite gneiss (Figure 2). Figure 1 shows the locations of the wells. Cations water samples were acidified with nitric acid to prevent the precipitation of the ions from the water. In-situ measurement of hydrogen ion concentration, electrical conductivity, total dissolved solid and total hardness were taken simultaneously with the sampling at each point using Water Quality Tester (Model pH-03; ORP-100, S-100; EZ-9902; C-600). The water samples were analyzed in the laboratory using spectrometry and flame photometry analytical technique (Model: BUCK Scientific ACCUSYS 211) for anions and cations respectively.

2.3 Geo-data Evaluation (Mathematical Expressions of the Parametric Indices)

In this research, the following chemical indices were used to evaluate the quality of the sampled groundwater: sodium adsorption ratio, magnesium absorption ratio, percentage sodium, permeability index, Kelly ratio, residual sodium carbonate (RSC), indexes of base exchange, contamination factor, degree of contamination and Revelle index.

2.3.1 Sodium Adsorption Ratio (SAR)

When sodium ion is high in irrigation water relative to calcium ions, complex of ion-exchange may be saturated with sodium ion thereby leading to the destruction of the soil structure [11]. This will further hinder the adsorption of soluble nutrients from the soil by the plants/crops. The following equation was used to estimate possible sodium hazard in irrigation water [12]:

$$SAR = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}}{2}}} \tag{1}$$

The concept of SAR is also a measure of the extent of sodium ion comparative to calcium ion and magnesium ion in irrigation water. The ions are measured in meq/l. Value less than 10 indicates excellent, 10 -18 is good; 18 -26 is doubtful and >26 is unsuitable for irrigation purposes.

2.3.2 Magnesium Absorption Ratio (MAR)

Formula for calculating MAR have also been established [13]. Values <50 is mostly considered appropriate for irrigation purposes while values >50 is regarded as inappropriate. The ions are measures in meq/l.

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} * 100 \tag{2}$$

2.3.3 Sodium Percentage (Na %)

The permeability of the soil is lower when there is an increase in the concentration of Na^+ in water for irrigation [14]. Wilcox [15] put forward a formula to evaluate sodium hazard in irrigation water. Mathematically it is expressed as:

$$Na\% = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} * 100 \tag{3}$$

Value less than 20 is considered excellent; 20 -40 is good; 40 – 60 is permissible; 60 – 80 is doubtful and > 80 is inappropriate for irrigation.

2.3.4 Permeability Index (PI)

Permeability of agricultural soil is adversely affected by continuous use of irrigation water over a very long period of time and this is induced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- contents in the soil [16]. The permeability index for this study was calculated using the following equation [17], with concentrations unit are in meq/l:

$$PI = 100\times [([Na^+] + [HCO_3^-]\ 1/2) / [Na^+] + [Ca^{2+}] + [Mg^{2+}] \tag{4}$$

2.3.5 Kelly Ratio (KR)

The Kelly’s ratio was evaluated by employing the following equation [18] as:

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \tag{5}$$

Concentrations are measured in meq/l. Value >1 is considered unsuitable for irrigation purposes while value <1 is considered suitable.

2.3.6 Residual Sodium Carbonate (RSC)

Values were computed for RSC to determine the harmful effect of carbonate and bicarbonate on the quality of the water for the purpose of agricultural practices [19]. This is calculated from the following mathematical equation, with concentration of the ions are in meq/l:

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \tag{6}$$

2.3.7 Indices of Base Exchange

The chemical alterations of groundwater along flow path can be explained clearly by examining the Chloro-Alkaline Indices (CAI) [2]. The Chloro-Alkaline Indices are best calculated from the following mathematical formulae:

$$\text{Chloro-Alkaline Indices I} = [Cl - (Na + K)]/Cl \tag{7}$$

$$\text{Chloro-Alkaline Indices, I} = [Cl^- - (Na^+ + K^+)]/SO_4^{2-} + HCO_3^{-} + CO_3^{2-} + NO_3^- \tag{8}$$

When there is positive Chloro-Alkaline Indices, it indicates exchange of Na ions and K ions from the water with Mg ions and Ca ions of the rocks and it is opposite (that is negative) when there is an exchange of Mg ions and Ca ions of the groundwater with Na ions and K ions of the surrounding rocks [20], [2].

2.3.8 Contamination Factor (CF)

This is determined by the following relation:

$$Cf = \frac{Cm}{Bm} \quad (9)$$

Where C_F gives the contamination factor of the singular element of interest; B_M connotes the background concentration in this study and C_M represents the concentration of the element in the water sample analyzed. Atiemo et al. [21] categorized CF into four classes viz: CF < 1 implies low contamination factor; 1 – 3 = moderate contamination factor; 3-6= considerable contamination factor and > 6= very high contamination factor.

2.3.9 Degree of Contamination

The method used by Atiemo [21] was adopted in this research. Degree of Contamination presents the summation of all the contamination factors in one singular sample. It is calculated by using the following mathematical equation:

$$C_{deg} = \sum (C_M/B_M) \quad (10)$$

Where,
C_M = concentration of water from the analyzed result
B_M=local background concentration (value) of metal, within the original area of the catchment

The Degree of Contamination were divided into Four categories viz: < 8 = low degree of contamination; 8 – 16 = considerable degree of contamination; 16 – 32 = high degree of contamination; > 32 = very high degree of contamination.

2.3.10 Revelle Index (RI)

The determination of groundwater quality is also determined by the level of the anions present in the water phase. Based on this, Revelle index is widely used to determine the quality of water. Revelle index < 1 indicates good water quality. The calculation of the index is based on the ionic ratio below [22]:

$$Cl/ (CO_3 + HCO_3) \text{ in meq/l} \quad (11)$$

3. Result and Discussion

3.1 Physicochemical Results

The results of the physicochemical parameters of groundwater in the study area are presented and illustrated in Appendix 1 and Figure 3 respectively. The hydrogen ion concentration ranged from 6.9 to 7.1 with an average and standard deviation of 7.02 and 0.07 respectively. This shows that the water ranges from slightly acidic to moderately alkaline. The electrical conductivity also ranged from 140 to 960µS/cm with an average and standard deviation of 342.37µS/cm and 243.05 respectively. The Total Dissolved Solid (TDS) ranged from 95 to 640 ppm (mean, 230 ppm; standard deviation, 162.16). The physicochemical parameters average values are within recommendations for household consumptions [23].

Based on the mean values of the chemical parameters, the trend of major cations and anions concentrations is: $Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$ and $HCO_3^{-}>Cl^{-}>SO_4^{2-}>CO_3^{2-}$ respectively (Figures 4 and 5.). The concentrations of Ca^{2+} ranged from 20.8 to 64 ppm with an average of 43.4ppm. The range of Mg^{2+} concentrations is from 4.9 to 34.3 ppm with an average of 16 ppm. Singh *et al.*, [24] reported that Ca^{2+} and Mg^{2+} are very vital nutrients for both plants and animals (including man). It is also stated that they are useful in the development of bones, nervous system and cells development. They however, reported that there is likelihood of kidney stones development if high concentrations of Ca^{2+} in water are ingested over a long period of time. Fortunately, the values are within the prescribed limits for portable water [23].

The concentrations of sodium ion in the sampled water ranged from 9.7 to 79.7 ppm with an average of 21.1 ppm. 15.8% of the hand dug wells have values greater than recommended values while 84.2% have values within the prescribed limit [23]. Excess sodium intake in water causes hypertension, congenital diseases, kidney disorders and nervous disorders in man [25]. K^{+} ranged from 6.18 to 50.84ppm with an average of 13.3 ppm.

The recorded values of chloride in the sampled water range from 29.11 to 90 ppm with an average of 48.9 ppm. 100% of the values are quite above standard recommendations [23]. High concentration of Chloride in portable water leads to salty taste water and has a laxative effect on the consumers [26]. The values computed for Nitrate range from 2.1 to 39.8 ppm with an average of 8 ppm. The values are quite below published recommendations [23]. This shows that there is less influence of decaying organic matter and sewage injection. However, high concentration of Nitrate in water causes gastric-cancer, methaemoglobin-aemia, goiter, birth malformation and hypertension [25], [27]. Sulphate ranged from 8 to 104 ppm with an average of 28.42 ppm.

Sulphate is available in water as an inorganic salt of sulphate and also in hydrogen sulphide as a dissolved gas [28]. Compared with recommendations, the values are much lower than the prescribed limit of 400 ppm [23]. Bicarbonate (HCO_3^-) reacts with calcium carbonate and sulphate to give heat-retarding pipe clogging scale in electric kettles, boiling rings and other heat exchanging household equipment [28]. The source of bicarbonate in groundwater is from the weathering of rock types within the vicinity of the area as well as the dissolution of atmospheric carbon dioxide into the underground water. The results of the bicarbonate concentration ranged from 74 to 260 ppm with an average of 158.74 ppm. 94.7 % of the samples have HCO_3^- values above the recommended limit of 100 ppm [29].

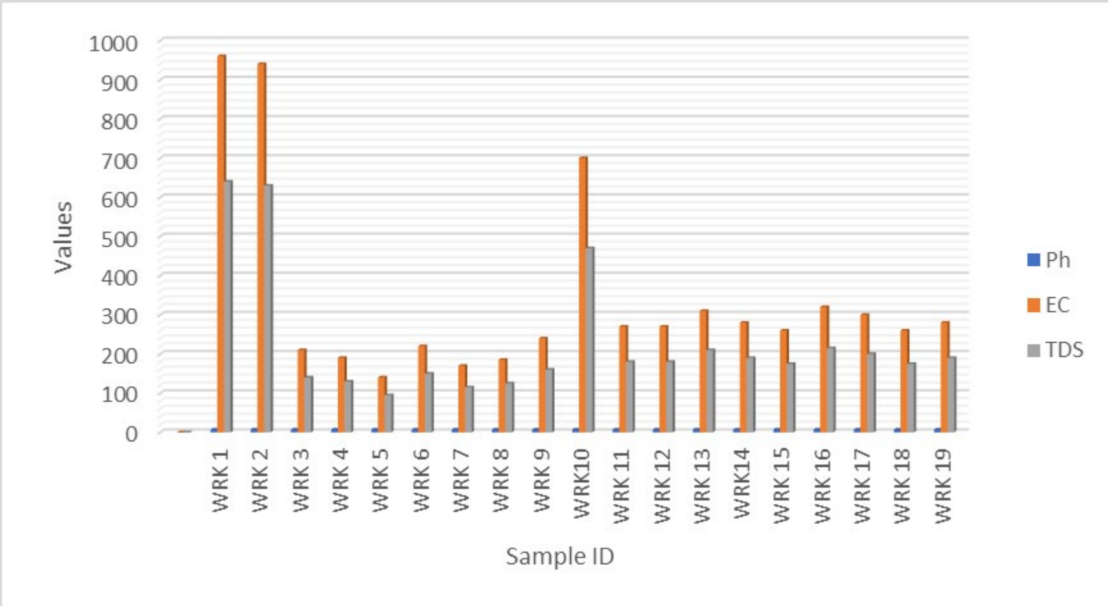

Fig. 3 *Profiles of physicochemical parameters in the study area*

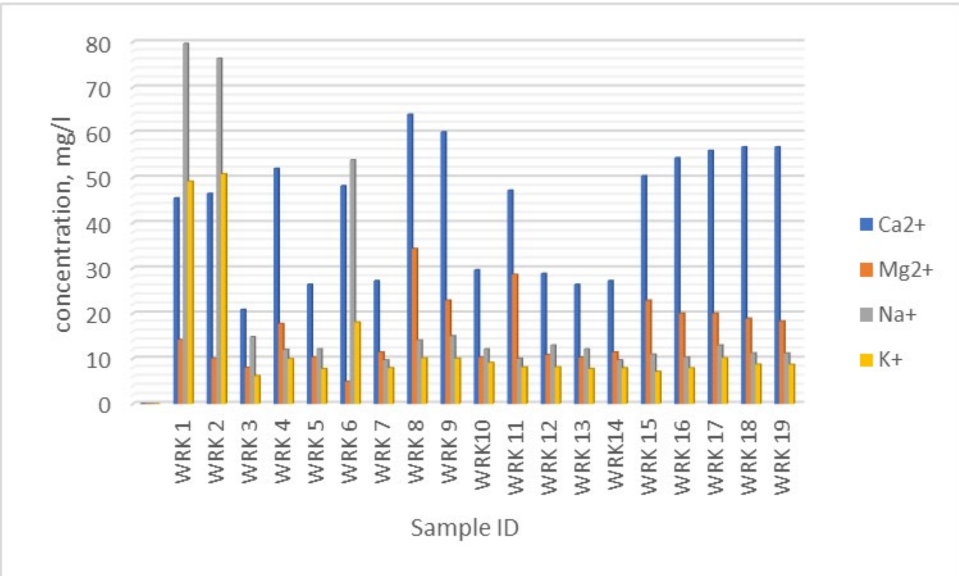

Fig. 4 *Profiles of major cations in the study area*

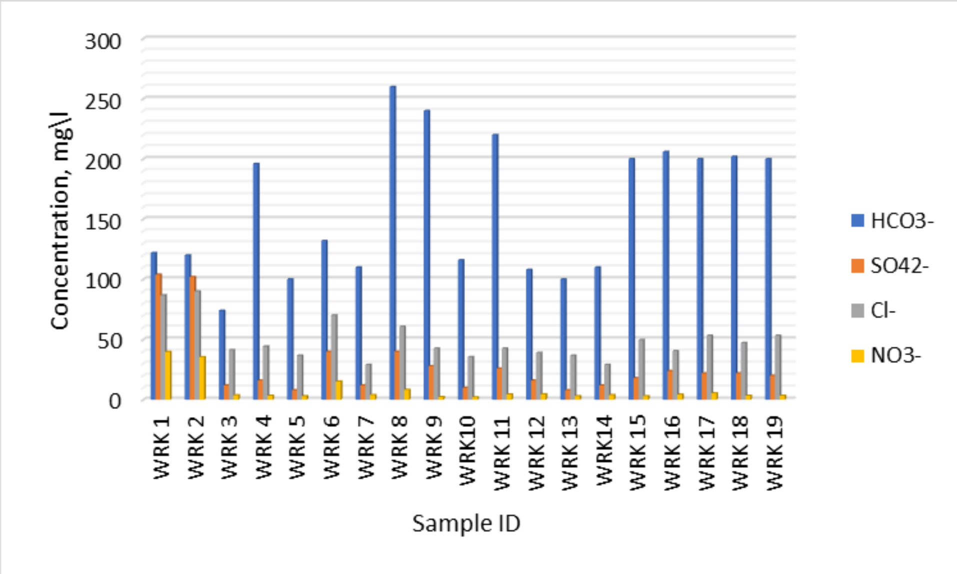

Fig. 5 *Profiles of major anions in the study area*

3.2 Assessment of Contamination

The assessment of contamination is carried out using Revelle index, Contamination Factor and Degree of Contamination. The statistical reports are presented in Appendix B. For the computed values of contamination factor, Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-} and CO_3^{2-} have an average value of 0.58, 0.54, 0.42, 0.24, 1.59, 0.28, 9.78, 0.16 and 0.01 respectively. The cations are generally of low contamination factors due to CF values less than 1. However, Na ion has CF greater than 1 in locations WRK 1, WRK 2 and WRK 6 respectively. This shows the influence of secondary weathering into the groundwater. HCO_3^{-} ranged from low contamination factor to moderate contamination factor. Cl^{-} ranged from considerable contamination factor to very high contamination factor. Respectively, HCO_3^{-} and Cl^{-} have average values of greater than one. This depicts more influence of human activities over the weathering of rock types in the area of study [30]. The profile of average CF is illustrated in Figure 6 and the profile of the standard deviation is illustrated in Figure 7.

The values calculated for Degree of contamination ranged from 8 to 24 with an average of 14. Fifteen hand dug wells (78.9 %) fall within moderate degree of contamination while four hand dug wells (21.1 %) fall within considerable degree of contamination. The profile of the degree of contamination is illustrated in Figure 8.

The values computed for the Revelle Index ranged from 0.31 to 1.17 with an average value of 0.57. 10.5% of the samples are greater than 1 (locations WRK 1 and WRK 2) while 89.5 % are less than 1. Based on Revelle index, all wells are of good quality while hand dug wells WRK 1 and WRK 2 are not of good quality as portable water. The Profile of Revelle Index values computed for each location is illustrated in Figure 9.

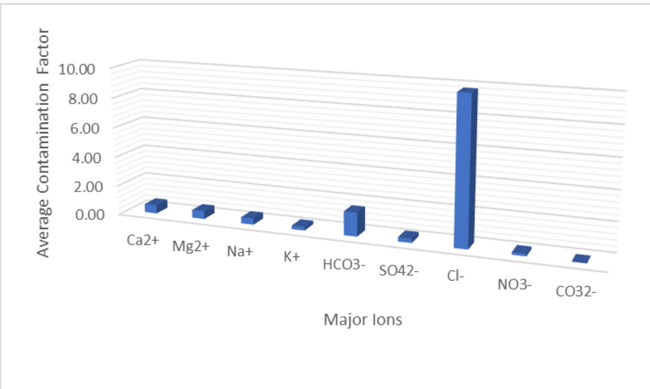

Fig. 6 *Profile of average contamination factor for the computed parameters in the study area*

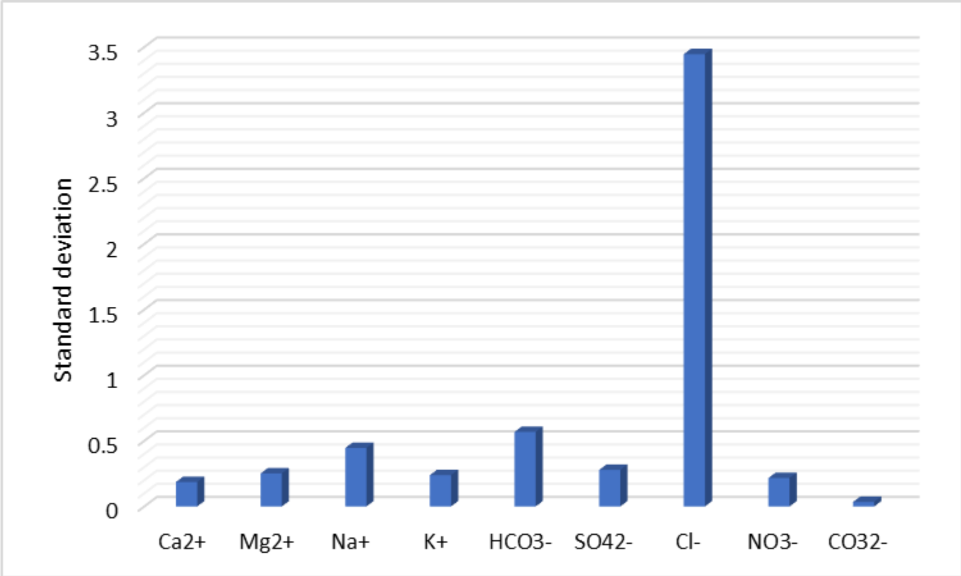

Fig. 7 *Standard deviation profile of the contamination factor*

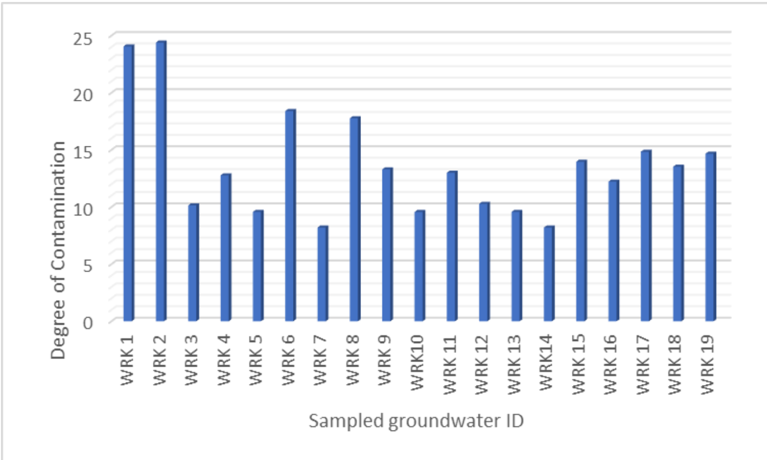

Fig. 8 *Profile of Degree of contamination for each hand dug well sampled*

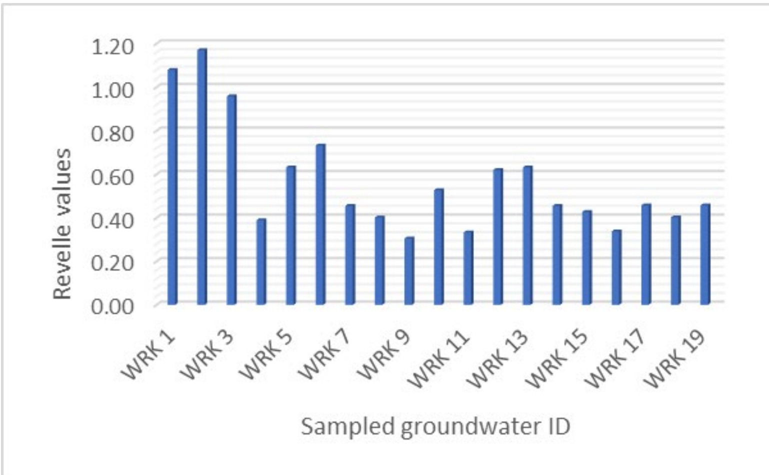

Fig. 9 *Profile of Revelle Index values computed for each location*

3.3 The Quality Appraisal of the Groundwater from the Study Area for Agricultural Purposes

Appendix C presents the statistical summary of the parameters for the quality appraisal of the groundwater resources in the study area for agricultural purposes. The quality appraisal of the groundwater from the study area for irrigation purpose is achieved using the following parameters as follows:

3.3.1 Total Hardness (TH)

The hand dug wells were examined for TH in-situ and the values ranged from 82 in hand dug well WRK 3 to 240 ppm in hand dug well WRK 8 with an average of 162.42 ppm. This implies that the water ranges from moderately hard to hard. Although, the values are less than 500 ppm as prescribed by WHO [23], however, it has been documented that if hard water is being consumed by all age groups for a very long time, it can result to urolithiasis, anencephaly, pre-natal mortality, cancer and cardiovascular disorder [25]. On the basis of suitability for irrigation, 57.9% falls under the category of moderately hard and 42.1% of the samples fall under Hard [16]. Water hardness causes scaling of pots, boilers, reservoir, and pipes using for irrigation. Figure 10 gives the illustration of TH in the groundwater.

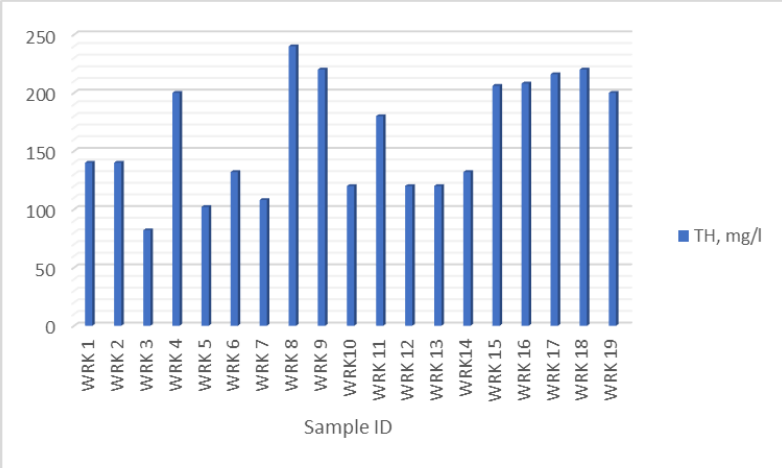

Fig. 10 *The profile of total hardness in the groundwater samples*

3.3.2 Electrical Conductivity

Electrical conductivity is also one of the parameters that serves as a measure of salinity hazard to growing crops. Abundance of salinity in soils reduces osmosis in plants thereby interfering with the intake of water and nutrients [31]. The values computed ranged from 140 to 960 µS/cm with an average of 342.37 µS/cm. 36.8% of the hand dug wells falls within excellent category for irrigation purposes, 52.6% falls within good and only 10.5% falls under permissible [16]. A bar chart for the measured EC is presented in Figure 11.

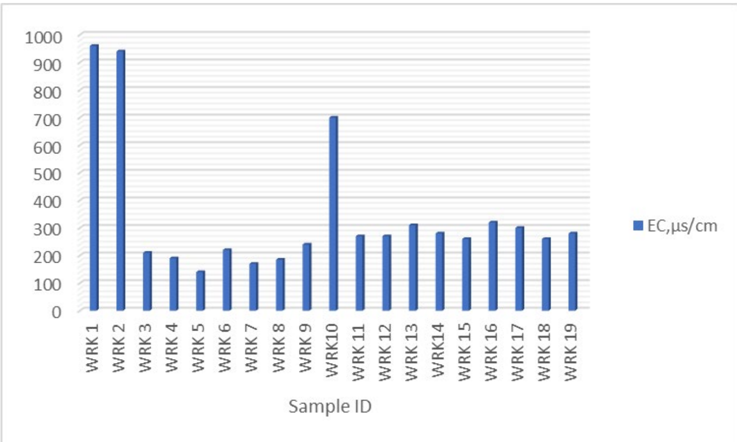

Fig. 11 *The profile electrical conductivity in the groundwater samples*

3.3.3 Total Dissolved Solids (TDS)

The salts of the major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) available in irrigation water may be injurious to growing plants thereby causing poor aeration to plants [28]. All the values measured are generally less than 1000 ppm (that is non-saline) and this makes the water free of problem associated with salinity for irrigation water. The graphical illustration is made available in Figure 12.

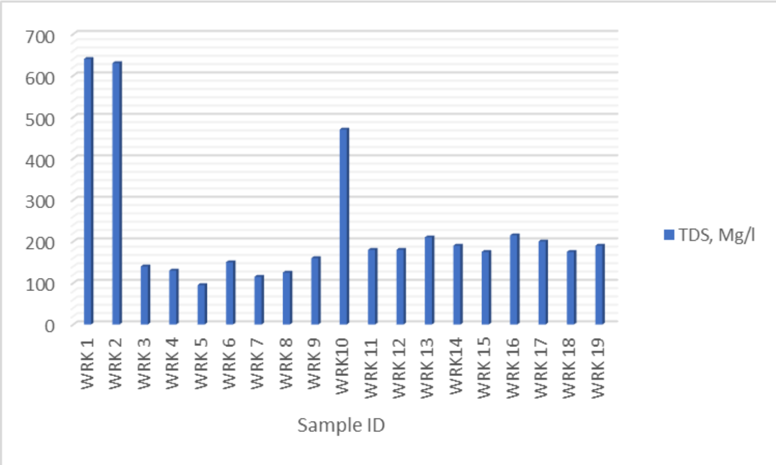

Fig. 12 *The profile of the total dissolved solid in the groundwater samples*

3.3.4 Sodium Adsorption Ratio (SAR)

The figures computed for SAR in the groundwater from the study area range from 0.28 in hand dug well WRK 11 to 2.64 in WRK 1 and WRK 2 respectively. The average is 0.73 with a standard deviation of 0.77. Based on these values, the groundwater in the area is excellent for irrigation practices with respect to SAR [22].

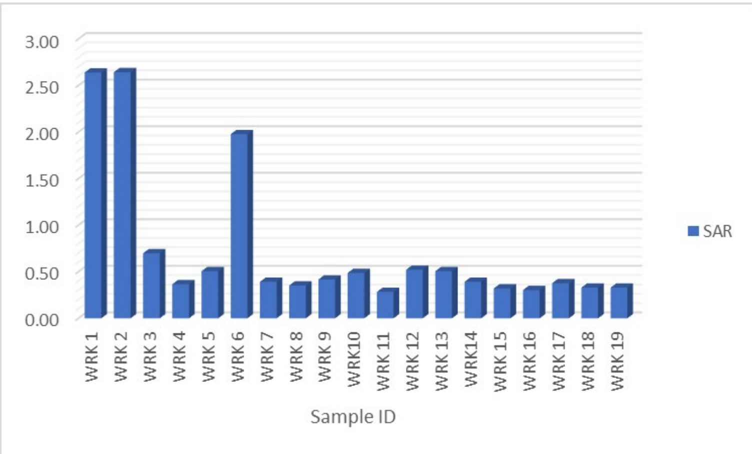

Fig. 13 *The profile of SAR in the groundwater samples*

3.3.5 Magnesium Ratio (MAR)

In general, Magnesium and Calcium uphold equilibrium in most water. However, at equilibrium, Magnesium ions influenced crop yields negatively [1],[20],[33]. From the data computed for the study area, MAR ranged from 14.54 to 50.20. Based on the value calculated for MAR, the water source is suitable for irrigation purposes except for hand dug well WRK 11. Hence caution needs to be taken in utilizing the well for irrigation processes. Figure 14 presents the profile of the plotted values for MAR.

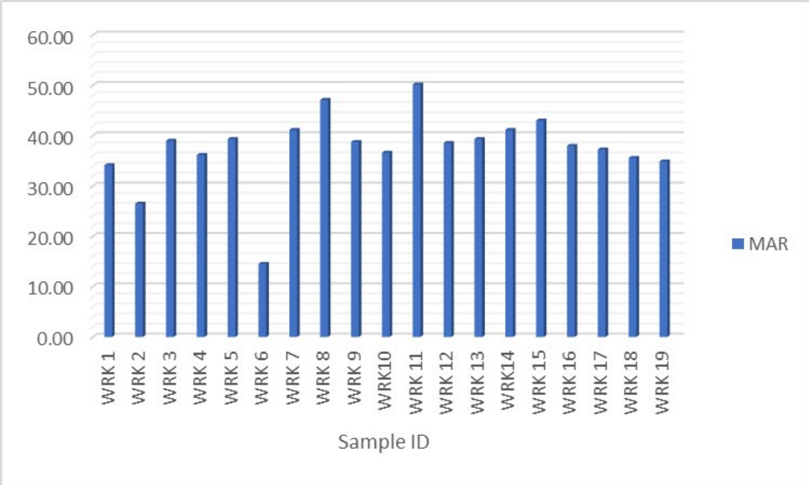

Fig. 14 *The profile of MAR in the water samples*

3.3.6 Percentage Sodium (%Na)

The percentage of sodium, also known as soluble sodium percentage ranged from 11.97 in location WRK 11 to 59.42% in location WRK 2. The standard deviation, median and average values are: 15.04, 21.28 and 24.57 respectively. According to Wilcox classification for irrigation water, 47.4% of the groundwater sampled and analyzed fall within the excellent category, 36.8% falls under Good and 15.8% falls under permissible. Figure 15 presents the profile of the computed values.

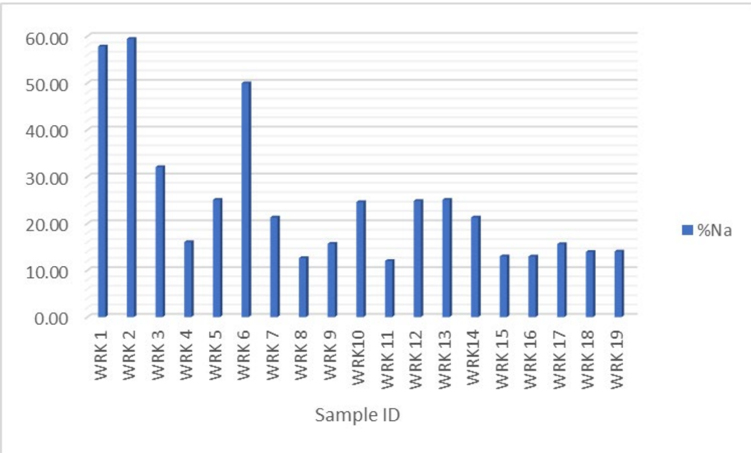

Fig. 15 *The profile of the Na% in the groundwater samples*

3.3.7 Permeability Index (PI)

It has been documented that the permeability of soil can be influenced by long-term use of irrigation water with excess of calcium, sodium and magnesium. The PI values computed ranged from 73.26 to 87.4 with an average of 79.99%. this mean that the water ranged from good to suitable- Class II to Class I [17], [20].

3.3.8 Kelly Index (KI)

Kelly index computed ranged from 0.09 to 1.05 with an average of 0.29. Only locations WRK 1 and WRK 2 have values slightly greater than one and the two hand dug wells might not be advisable to be utilized for irrigation purposes [33]. Figure 16 illustrates the profile of the Kelly index.

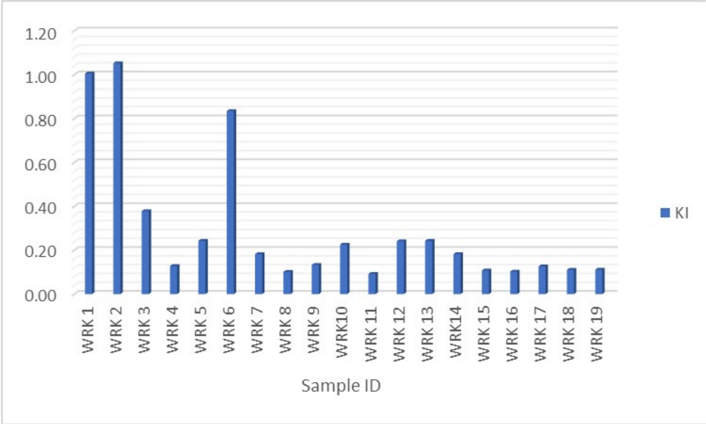

Fig. 16 *The profile of the KI in the groundwater samples*

3.3.9 Residual Sodium Carbonate (RSC)

The values calculated for RSC are generally less than one (Figure 17). Based on these values for RSC, the groundwater resources are fit for irrigation practices [19].

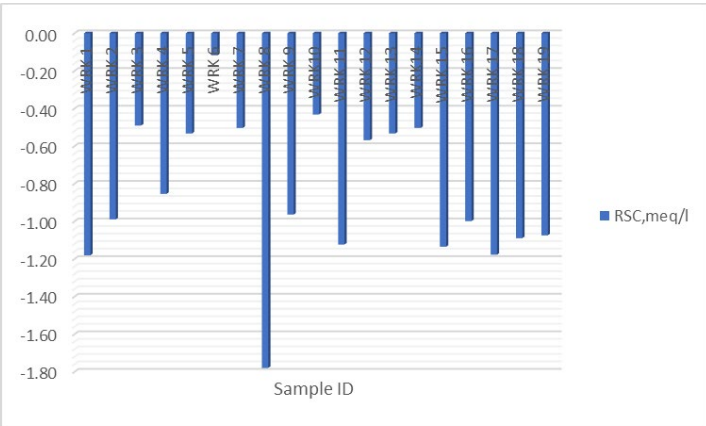

Fig. 17 *The profile of RSC in the groundwater samples*

3.3.10 Indices of Base Exchange

From the values computed, CIA-1 ranged from -0.48 to 0.64 with an average of 0.38. CIA-2 ranged from -0.28 to 1.53 with a mean of 0.87. 15.8% of the wells have negative CIA 1 and CIA-2 respectively (WRK 1, WRK 2 and WRK 3) and 84.2% of the wells have positive CIA-1 and CIA-2 respectively. The implications of these are that hand dug wells WRK 1, WRK 2 and WRK 3 with negative values have exchange of sodium ions and potassium ions from the groundwater with magnesium and calcium ions from the rock types in the study area, while the other hand dug wells with positive values only gained calcium and magnesium ions from the weathering of the surrounding rocks.

4. Conclusion

The groundwater quality of Iworoko-Ekiti and its environs has partly been established using chemical indices. In general, based on the chemical indices adopted for this research, almost all the groundwater in the area is suitable for irrigation except groundwater WRK 1 and WRK 2 that have Kelly index greater than 1 making them unsuitable for irrigation practices. The magnesium adsorption ratio for groundwater WRK 11 is slightly higher than 50, making the groundwater not suitable for irrigation purposes. The Degree of Contamination computed for WRK 1, WRK 2, WRK 6 and WRK 8 falls within considerable degree of contamination and this may pose threat for human consumption. In addition, measured pH values for hand dug wells WRK 1, WRK 4, WRK 7, WRK 8, WRK14 and WRK 16 are slightly acidic, and they are not within the recommended range of WHO for households' consumption.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Oladele Ajiboro Omotoso, Olusola Johnson Ojo, Sodeeq Gbolahan Usman, Hamidah Pearl Yakubu, Barakat Oluwatimileyin Owoseni, Daniel Eromosele Ikheloa, Moses Onoruoiza Malachi;* ***data collection:*** *Oladele Ajiboro Omotoso, Olusola Johnson Ojo, Sodeeq Gbolahan Usman, Hamidah Pearl Yakubu, Barakat Oluwatimileyin Owoseni, Daniel Eromosele Ikheloa, Moses Onoruoiza Malachi;* ***analysis and interpretation of results:*** *Oladele Ajiboro Omotoso, Olusola Johnson Ojo, Sodeeq Gbolahan Usman, Hamidah Pearl Yakubu, Barakat Oluwatimileyin Owoseni, Daniel Eromosele Ikheloa, Moses Onoruoiza Malachi;* ***draft manuscript preparation:*** *Oladele Ajiboro Omotoso, Olusola Johnson Ojo, Sodeeq Gbolahan Usman, Hamidah Pearl Yakubu, Barakat Oluwatimileyin Owoseni, Daniel Eromosele Ikheloa, Moses Onoruoiza Malachi. All authors reviewed the results and approved the final version of the manuscript.*

Appendix

Appendix A *Physicochemical parameters and major ions (ppm) with their statistical summaries in the analyzed groundwater samples of Iworoko-Ekiti, SW Nigeria, including the samples coordinates.*

		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	NO_3^{-}	CO_3^{2-}	Ph	EC, µs/cm	TDS, Mg/l
		WHO, ppm											
		75	30	50	-	-	500	5	50	-	7.0-8.5	-	-
Coordinates	Sample Codes	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	NO_3^{-}	CO_3^{2-}	Ph	EC, µs/cm	TDS, Mg/l
7°43′14″ N, 5°17′5″ E	WRK 1	45.5	14.18	79.68	49.2	122	104	86.83	39.78	8	6.98	960	640
7°43′17″ N, 5°17′9″ E	WRK 2	46.5	10.08	76.36	50.84	120	102	90.03	35.45	6	7.03	940	630
7°43′10″ N, 5°17′14″ E	WRK 3	20.82	8.01	14.82	6.18	74	12	41.27	3.79	0	7.01	210	140
7°43′4″ N, 5°17′18″ E	WRK 4	52.02	17.73	12	9.93	196	16	44.38	3.35	0	6.86	190	130
7°43′27″ N, 5°17′46″ E	WRK 5	26.4	10.3	12.13	7.76	100	8	36.77	3	0	7.04	140	95
7°43′30″ N, 5°17′45″ E	WRK 6	48.2	4.93	53.95	18.04	132	40	70.14	15.17	16	7.00	220	150
7°43′42″ N, 5°17′44″ E	WRK 7	27.2	11.44	9.68	7.92	110	12	29.11	3.95	0	6.91	170	115
7°43′34″ N, 5°17′31″ E	WRK 8	64	34.32	14.08	10.11	260	40	60.7	8.32	0	6.99	185	125
7°43′40″ N, 5°17′8″ E	WRK 9	60.11	22.88	15.01	10.02	240	28	42.6	2.36	0	7.07	240	160
7°43′38″ N, 5°17′12″ E	WRK10	29.63	10.3	12.1	9.12	116	10	35.59	2.08	0	7.01	700	470
7°43′37″ N, 5°17′15″ E	WRK 11	47.21	28.61	10.02	8.11	220	26	42.6	4.48	0	7.08	270	180
7°43′37″ N, 5°17′18″ E	WRK 12	28.8	10.87	12.96	8.12	108	16	38.96	4.61	0	7.10	270	180
7°43′46″ N, 5°17′6″ E	WRK 13	26.4	10.3	12.13	7.76	100	8	36.77	3	0	7.06	310	210
7°43′49″ N, 5°17′9″ E	WRK14	27.2	11.44	9.68	7.92	110	12	29.11	3.95	0	6.99	280	190
7°43′48″ N, 5°17′2″ E	WRK 15	50.4	22.88	10.96	7.11	200	18	49.69	3.04	0	7.00	260	175
7°43′41″ N, 5°17′58″ E	WRK 16	54.4	20.02	10.32	7.91	206	24	40.47	4.32	0	6.91	320	215
7°43′42″ N, 5°17′56″ E	WRK 17	56	20.02	12.96	10.12	200	22	53.25	5.36	0	7.11	300	200
7°43′37″ N, 5°17′59″ E	WRK 18	56.8	18.88	11.24	8.7	202	22	47.25	3.41	0	7.10	260	175
7°43′39″ N, 5°17′54″ E	WRK 19	56.81	18.3	11.18	8.69	200	20	53.25	3.35	0	7.04	280	190
	Average	43.39	16.08	21.12	13.35	158.74	28.42	48.88	8.04	1.58	7.02	342.37	230.00
	Minimum	20.82	4.93	9.68	6.18	74.00	8.00	29.11	2.08	0.00	6.86	140.00	95.00
	Maximum	64.00	34.32	79.68	50.84	260.00	104.00	90.03	39.78	16.00	7.11	960.00	640.00
	Standard Dev.	14.01	7.56	22.29	13.15	56.77	27.86	17.23	10.84	4.14	0.07	243.05	162.16
	Variance	196.28	57.12	496.98	172.99	3222.76	776.26	296.92	117.54	17.15	0.00	59073.25	26297.22
	Median	47.21	14.18	12.13	8.69	132	20	42.6	3.95	0	7.01	270	180

Appendix B *The contamination indexes statistical analyses of hydrogeochemical parameters in the study area*

Sample Code	Contamination Factor										
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^-	CO_3^{2-}	Degree Of Contamination	Revelle Index
WRK 1	0.61	0.47	1.59	0.89	1.22	1.04	17.37	0.80	0.07	24	1.08
WRK 2	0.62	0.34	1.53	0.92	1.20	1.02	18.01	0.71	0.05	24	1.17
WRK 3	0.28	0.27	0.30	0.11	0.74	0.12	8.25	0.08	0.00	10	0.96
WRK 4	0.69	0.59	0.24	0.18	1.96	0.16	8.88	0.07	0.00	13	0.39
WRK 5	0.35	0.34	0.24	0.14	1.00	0.08	7.35	0.06	0.00	10	0.63
WRK 6	0.64	0.16	1.08	0.33	1.32	0.40	14.03	0.30	0.13	18	0.73
WRK 7	0.36	0.38	0.19	0.14	1.10	0.12	5.82	0.08	0.00	8	0.45
WRK 8	0.85	1.14	0.28	0.18	2.60	0.40	12.14	0.17	0.00	18	0.40
WRK 9	0.80	0.76	0.30	0.18	2.40	0.28	8.52	0.05	0.00	13	0.31
WRK10	0.40	0.34	0.24	0.17	1.16	0.10	7.12	0.04	0.00	10	0.53
WRK 11	0.63	0.95	0.20	0.15	2.20	0.26	8.52	0.09	0.00	13	0.33
WRK 12	0.38	0.36	0.26	0.15	1.08	0.16	7.79	0.09	0.00	10	0.62
WRK 13	0.35	0.34	0.24	0.14	1.00	0.08	7.35	0.06	0.00	10	0.63
WRK14	0.36	0.38	0.19	0.14	1.10	0.12	5.82	0.08	0.00	8	0.45
WRK 15	0.67	0.76	0.22	0.13	2.00	0.18	9.94	0.06	0.00	14	0.43
WRK 16	0.73	0.67	0.21	0.14	2.06	0.24	8.09	0.09	0.00	12	0.34
WRK 17	0.75	0.67	0.26	0.18	2.00	0.22	10.65	0.11	0.00	15	0.46
WRK 18	0.76	0.63	0.22	0.16	2.02	0.22	9.45	0.07	0.00	14	0.40
WRK 19	0.76	0.61	0.22	0.16	2.00	0.20	10.65	0.07	0.00	15	0.46
Average	0.58	0.54	0.42	0.24	1.59	0.28	9.78	0.16	0.01	14	0.57
Minimum	0.28	0.16	0.19	0.11	0.74	0.08	5.82	0.04	0.00	8	0.31
Maximum	0.85	1.14	1.59	0.92	2.60	1.04	18.01	0.80	0.13	24	1.17
Standard Deviation	0.19	0.25	0.45	0.24	0.57	0.28	3.45	0.22	0.03	5	0.25
Variance	0.03	0.06	0.20	0.06	0.32	0.08	11.88	0.05	0.00	22	0.06
Median	0.63	0.47	0.24	0.16	1.32	0.20	8.52	0.08	0.00	13	0.46

Appendix C *The parameters for the quality appraisal of the groundwater resources in the study area for agricultural purposes*

Sample Code	SAR	RSC,meq/l	%Na	TH, Mg/l	KI	EC,µs/cm	TDS, Mg/l	PI	MAR	CIA-1 and CIA-2(Indices of base exchange)	
WRK 1	2.64	-1.18	57.81	140	1.01	960	640	79.07	34.14	-0.484	-0.277
WRK 2	2.64	-0.99	59.42	140	1.05	940	630	81.64	26.50	-0.413	-0.259
WRK 3	0.70	-0.49	32.03	82	0.38	210	140	79.11	39.02	0.491	1.284
WRK 4	0.37	-0.85	16.02	200	0.13	190	130	81.39	36.18	0.506	1.160
WRK 5	0.51	-0.53	25.05	102	0.24	140	95	80.27	39.35	0.459	1.535
WRK 6	1.98	-0.12	49.94	132	0.83	220	150	87.40	14.54	-0.026	-0.026
WRK 7	0.39	-0.50	21.28	108	0.18	170	115	81.55	41.16	0.395	0.722
WRK 8	0.35	-1.78	12.60	240	0.10	185	125	73.26	47.14	0.601	0.756
WRK 9	0.42	-0.96	15.66	220	0.13	240	160	82.64	38.76	0.412	0.579
WRK10	0.49	-0.43	24.56	120	0.23	700	470	84.90	36.63	0.404	1.190
WRK 11	0.28	-1.12	11.97	180	0.09	270	180	78.25	50.20	0.574	0.803
WRK 12	0.52	-0.57	24.80	120	0.24	270	180	80.41	38.56	0.459	0.868
WRK 13	0.51	-0.53	25.05	120	0.24	310	210	80.27	39.35	0.459	1.535
WRK14	0.39	-0.50	21.28	132	0.18	280	190	81.55	41.16	0.395	0.722
WRK 15	0.32	-1.14	12.98	206	0.11	260	175	76.79	43.02	0.636	1.503
WRK 16	0.30	-1.00	12.95	208	0.10	320	215	79.30	37.97	0.550	0.785
WRK 17	0.38	-1.18	15.58	216	0.13	300	200	76.55	37.29	0.567	1.103
WRK 18	0.33	-1.09	13.92	220	0.11	260	175	77.72	35.60	0.578	1.075
WRK 19	0.33	-1.07	14.00	200	0.11	280	190	77.79	34.88	0.627	1.430
Average	0.73	-0.84	24.57	162.42	0.29	342.37	230.00	79.99	37.44	0.378	0.868
Minimum	0.28	-1.78	11.97	82.00	0.09	140.00	95.00	73.26	14.54	-0.484	-0.277
Maximum	2.64	-0.12	59.42	240.00	1.05	960.00	640.00	87.40	50.20	0.636	1.535
Standard Dev.	0.77	0.39	15.04	49.42	0.31	243.05	162.16	3.15	7.44	0.325	0.558
Variance	0.59	0.15	226.15	2442.48	0.10	59073.25	26297.22	9.91	55.33	0.106	0.311
Median	0.39	-0.96	21.28	140.00	0.18	270.00	180.00	80.27	38.56	0.459	0.868

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